UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

# HYDROLOGIC CHARACTERIZATION OF LAND CLASSES AT WHITE TAIL BUTTE EMRIA STUDY AREA, WYOMING

by

Gregg C. Lusby



UNPUBLISHED DATA FOR ADMINISTRATIVE USE ONLY

# Hydrologic characterization of land classes at White Tail Butte EMRIA study area, Wyoming

by

Gregg C. Lusby

The White Tail Butte study area was divided into three major land classes, each of which possess runoff characteristics which are similar over its areal extent. Rainfall simulation runs were made on each of the land classes to determine the hydrologic characteristics of the class as baseline data for comparison with future changes which might occur from surface mining. The extent of each land class was determined from areal photographs and is shown on the accompanying map. A response similar to that obtained from the applied simulated rainfall could be expected from areas of the same hydrologic class shown on the map. The simulation sites were chosen to be representative of the terrain within each hydrologic class. However, runoff and sediment yield values may have to be altered somewhat to compensate for radically dissimilar slopes and soil depth.

Methods used to obtain the data from each simulation site listed in table 1 are as follows:

1. Runoff--Measured in a Parshall flume with 1 inch throat. Readings of stage made at 1 minute intervals and converted to discharge in cubic feet per second. From these data a runoff hydrograph was constructed and total volume of runoff was computed and expressed in inches per unit area. From these data an infiltration rate curve was also constructed by subtracting the runoff from the rainfall applied for each 1 minute interval and expressing as the infiltration rate in inches per hour.

2. Precipitation--Measured in a network of rain gages within the study area. Rainfall for the total area was computed using the Thiessen Polygon method.

3. Sediment yield--Water samples were obtained from the outflow at 3 minute intervals and were analyzed from sediment concentration. The sediment concentrations were plotted and a concentration curve was drawn between points. From this curve a concentration was obtained for each minute and was used in conjunction with the discharge for that minute to compute the sediment load. Total sediment load is expressed in pounds and in tons per square mile.

4. Area--Obtained from a topographic survey of the site. Expressed in square feet.

5. Weighted mean slope--Obtained by measuring the area between contours and weighting the slope of that area according to the percentage the area is of the whole.

6. Antecedent moisture--Obtained from gravimetric samples of the top 10 centimeters of soil. Samples are usually taken at four locations within the site and averaged for the final result. Expressed as percentage by weight. Two runs are normally made at each site. The first in a dry condition and again after water in the soil has come to a gravimetric equilibrium. Soil moisture samples are taken before each run.

7. Clay--Obtained from soil samples taken from the top 10 centimeters of soil at numerous locations within the site. Samples are analyzed for percentage by weight of material less than 0.002 millimeters in diameter.

8. Root concentration--The amount of fibrous root material in the top 10 centimeters of soil. Expressed in grams per 100 grams of soil.

9. Bare soil and rock--Obtained from three 20-foot transects within each site using a point frame and the first point contact method. Pins lowered to the vegetation or ground surface at 2 inch intervals are recorded as first encountering aerial vegetation, mulch, bare soil or rock. Expressed as hits per 100 pins.

10. Reconstructed runoff--Rainfall applied normally varies somewhat about the standard of 1.5 inches in 45 minutes. In order to compare runoff results on a standard basis, a runoff hydrograph is reconstructed using infiltration rates actually determined and rainfall amounts applied by the standard storm of 1.5 inches in 45 minutes.

## Chemical analyses

Samples of the outflow from each site were obtained at 3 minute intervals for chemical analyses. These samples were composited in sequential groups so that three or four samples were obtained for the entire runoff period. An analysis was made on each composite sample for the items listed in table 2. An analysis of the water applied is used as a standard, and other values listed are either an increase (+) or decrease (-) of these values in the runoff water.

## Precipitation

A frequency of recurrence of maximum daily precipitation during the months April through October at Gillette, Wyoming is shown on

figure 1. From this curve the following data on the magnitude of storms of various recurrence interval were obtained. These data give a general idea of storms in the vicinity of the study area.

| Recurrence Interval (years) | Precipitation (inches) |
|---|---|
| 2.33 | 1.71 |
| 10 | 2.74 |
| 25 | 3.19 |
| 50 | 3.77 |

A description of each study site and of each hydrologic class follows. A list of precipitation events of different recurrence intervals and durations that were obtained from Weather Bureau Technical Paper 40 are also shown for each site. The volume of runoff that might be expected from storms of this type was computed using infiltration rates obtained from the original simulation events.

## Hydrologic Class A

This class consists of the tops of numerous small conical-shaped hills in the study area. The underlying material is made up of scoria which is very permeable. No appreciable increase in runoff was noted after the soil had been wetted. The following data was obtained from the simulation site.

Weighted mean slope = 18.4 percent
Clay = 22.2 percent
Bare soil and rock = 7.7 percent

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

| RI/D/M | AM = 5.7 | AM = 24.0 |
|---|---|---|
| 2/30/0.60 | 0 | 0 |
| 10/30/1.05 | .08 | .08 |
| 25/30/1.30 | .29 | .36 |
| 50/30/1.50 | .35 | .54 |
| 2/60/0.80 | 0 | 0 |
| 10/60/1.30 | 0 | 0 |
| 25/60/1.60 | 0 | 0 |
| 50/60/1.80 | 0 | 0 |

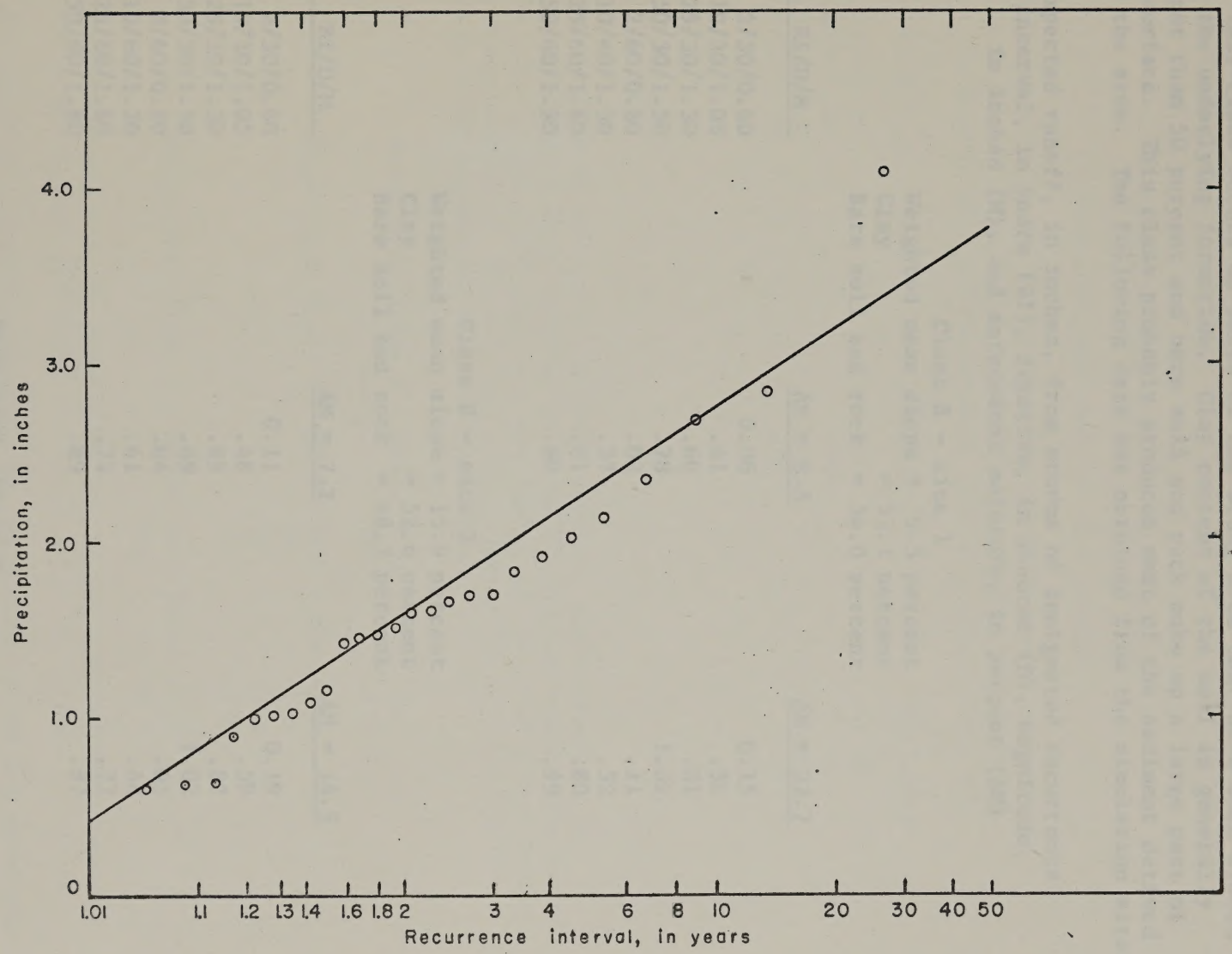



Figure 1.--Recurrence of maximum yearly 24 hour rainfall (Apr-Oct) at Gillette, Wyo.

## Hydrologic Class B

This class occurs on parts of the study area that have been eroded into the underlying formation. Clay content of the soil is generally greater than 50 percent and bare soil and rock make up a large part of the surface. This class probably produces most of the sediment derived from the area. The following data was obtained from the simulation sites.

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

Class B - site 1
Weighted mean slope = 9.5 percent
Clay = 53.1 percent
Bare soil and rock = 34.0 percent

| RI/D/M | AM = 8.5 | AM = 22.7 |
|---|---|---|
| 2/30/0.60 | 0.06 | 0.15 |
| 10/30/1.05 | .41 | .56 |
| 25/30/1.30 | .60 | .81 |
| 50/30/1.50 | .78 | 1.02 |
| 2/60/0.80 | .02 | .11 |
| 10/60/1.30 | .37 | .52 |
| 25/60/1.60 | .61 | .80 |
| 50/60/1.80 | .80 | .99 |

Class B - site 2
Weighted mean slope = 15.9 percent
Clay = 52.6 percent
Bare soil and rock = 48.7 percent

| RI/D/M | AM = 7.2 | AM = 14.5 |
|---|---|---|
| 2/30/0.60 | 0.11 | 0.19 |
| 10/30/1.05 | .48 | .59 |
| 25/30/1.30 | .69 | .82 |
| 50/30/1.50 | .89 | 1.02 |
| 2/60/0.80 | .04 | .05 |
| 10/60/1.30 | .41 | .48 |
| 25/60/1.60 | .71 | .77 |
| 50/60/1.80 | .89 | .97 |

## Hydrologic Class C

This class supports an excellent stand of grass which inhibits erosion even though runoff is fairly high. It is contained in many

of the grassy swales which show no signs of cutting and actually may be agrading. Slopes range from almost flat to fairly steep on some of the well-vegetated hillsides. The following data was obtained from the simulation site.

Weighted mean slope = 6.1 percent
Clay = 24.2 percent
Bare soil and rock = 8.0 percent

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

| RI/D/M | AM = 11.5 | AM = 27.0 |
|---|---|---|
| 2/30/0.60 | 0 | 0 |
| 10/30/1.05 | .18 | .34 |
| 25/30/1.30 | .37 | .57 |
| 50/30/1.50 | .58 | .80 |
| 2/60/0.80 | 0 | 0 |
| 10/60/1.30 | 0 | .12 |
| 25/60/1.60 | .14 | .35 |
| 30/60/1.80 | .30 | .55 |

The following curves for runoff, sediment concentration, and infiltration rates were obtained from the simulation sites. The horizontal part of the infiltration curve indicates that the actual infiltration rate exceeded the rainfall rate. The curves are related to the hydrologic classes by the following key.

| | | |
|---|---|---|
| Hydrologic Class A - | White Tail Butte | 3-1 |
| | Do. | 3-2 |
| Hydrologic Class B - | White Tail Butte | 1-1 |
| | Do. | 1-2 |
| | Do. | 2-1 |
| | Do. | 2-2 |
| Hydrologic Class C - | White Tail Butte | 4-1 |
| | Do. | 4-2 |

Water discharge is in cubic feet per second and sediment concentration in milligrams per liter.

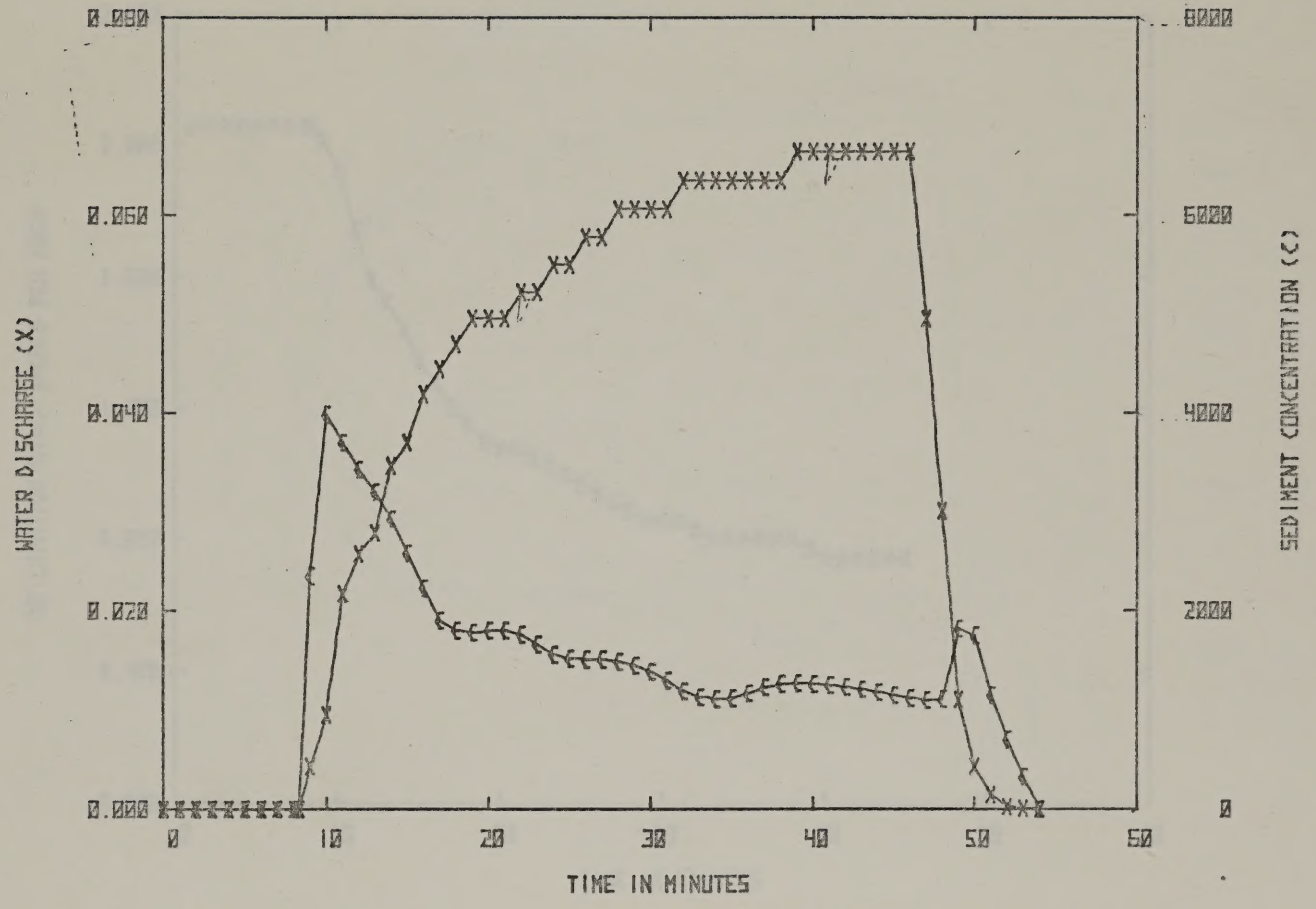
Pictures that are available for the simulation sites are provided to aid in the identification of the hydrologic classes.

Table 1.--Data obtained from simulation sites at White Tail Butte study area

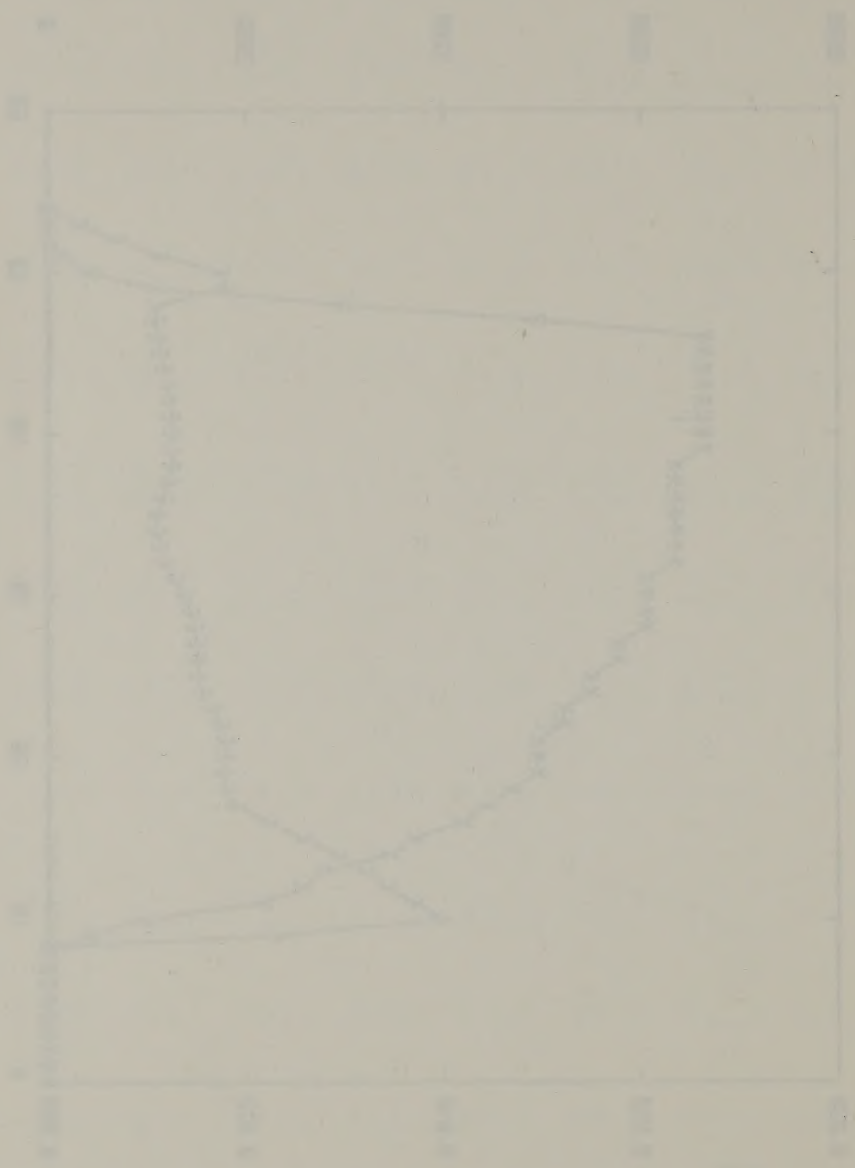
| Variable | Site | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-1 | 1-2 | 2-1 | 2-2 | 3-1 | 3-2 | 4-1 | 4-2 |
| Date | 8-19-76 | 8-20-76 | 8-22-76 | 8-23-76 | 8-17-76 | 8-18-76 | 8-12-76 | 8-13-76 |
| Area (sq. ft.) | 2,194 | 2,194 | 1,976 | 1,976 | 2,298 | 2,298 | 3,194 | 3,194 |
| Weighted mean slope (percent) | 9.5 | 9.5 | 15.9 | 15.9 | 18.4 | 18.4 | 6.1 | 6.1 |
| Antecedent moisture (percent) | 8.5 | 22.7 | 7.2 | 14.5 | 5.7 | 24.0 | 11.5 | 27.0 |
| Clay (percent) | 53.1 | 53.1 | 52.6 | 52.6 | 22.2 | 22.2 | 24.2 | 24.2 |
| Root concentration (g/100 g) | 2.628 | 2.628 | .848 | .848 | 2.484 | 2.484 | 1.206 | 1.206 |
| Bare soil and rock (percent) | 34.0 | 34.0 | 48.7 | 48.7 | 7.7 | 7.7 | 8.0 | 8.0 |
| Precipitation (inches) | 1.56 | 1.71 | 1.82 | 1.69 | 1.51 | 1.57 | 1.61 | 1.57 |
| Runoff (inches) | .69 | 1.05 | 1.01 | 1.01 | .03 | .05 | .40 | .67 |
| Sediment | | | | | | | | |
| pounds | 11.74 | 15.97 | 37.79 | 44.02 | .17 | .64 | 2.27 | 3.20 |
| tons per sq. mi. | 74.6 | 101 | 267 | 311 | 1.0 | 3.9 | 9.9 | 14.0 |
| Reconstructed runoff (inches) | .68 | .87 | .73 | .87 | .10 | .10 | .30 | .51 |

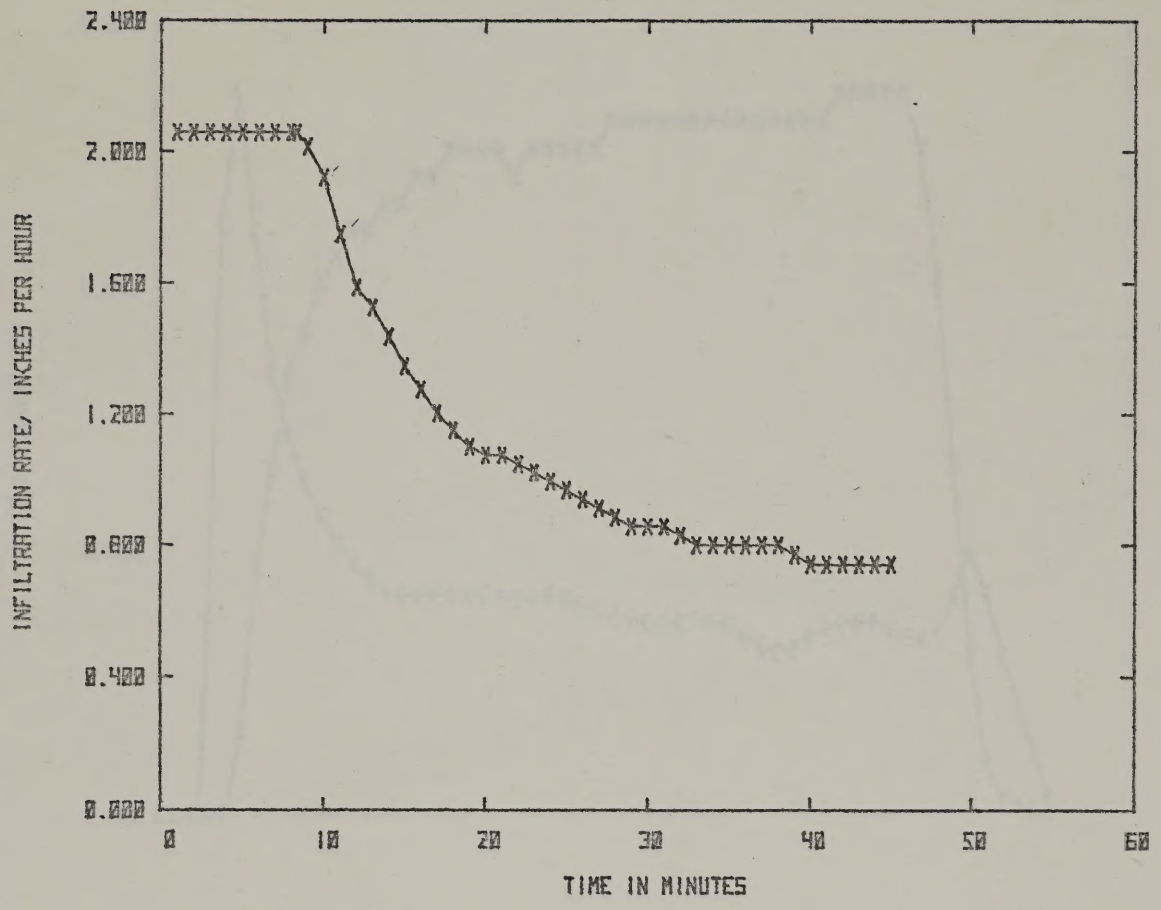
Table 2.--Changes in water chemistry (+ or -) of runoff water as compared to applied water

| Site | Composite | Variable | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cations (mg/L) | | | | Anions (mg/L) | | | | | | Total Cations | Total Anions |
| | | pH | Specific Conduct. | Residue mg/L | Calcium | Magnesium | Potassium | Sodium | Bicarb. | Carbonate | Chloride | Flouride | Sulfate | $NO_2+NO_3$ | MEQ/L | MEQ/L |
| White Tail 1-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | + .1 | + 57 | +33 | + 6 | + .6 | +2.0 | +2.3 | +24 | 0 | +1.4 | +.1 | +1 | +1.3 | +.513 | + .551 |
| | 2 | + .2 | + 43 | +16 | + 4 | + .1 | +2.0 | + .1 | +17 | 0 | +1.3 | +.1 | -2 | + .3 | +.263 | + .302 |
| | 3 | + .2 | + 35 | +16 | + 3 | -.2 | +1.8 | + .3 | +23 | 0 | + .6 | +.1 | -1 | - .1 | +.192 | + .372 |
| White Tail 1-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .4 | + 56 | +26 | + 9 | + .8 | +2.0 | +1.2 | +21 | 0 | + .6 | +.1 | 0 | + .03 | +.568 | + .369 |
| | 2 | - .1 | + 47 | +22 | + 5 | + .1 | +1.4 | +1.0 | +25 | 0 | + .4 | +.1 | -1 | + .01 | +.337 | + .406 |
| | 3 | - .1 | + 36 | +14 | + 5 | + .3 | +2.0 | + .6 | +12 | 0 | 0 | +.1 | -1 | - .07 | +.331 | + .176 |
| White Tail 2-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .2 | +131 | +70 | +19 | +3.3 | +5.0 | + .5 | +61 | 0 | +4.2 | +.1 | +4 | + .28 | 1.369 | +1.227 |
| | 2 | 0 | + 81 | +38 | +13 | +1.7 | +1.3 | + .2 | +39 | 0 | + .4 | +.1 | 0 | + .01 | +.830 | + .657 |
| | 3 | 0 | + 68 | +31 | +11 | +1.1 | +1.5 | + .2 | +32 | 0 | + .6 | +.1 | +1 | 0 | +.686 | + .526 |
| White Tail 2-2 | Applied | 7.5 | +208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .1 | + 99 | +54 | +13 | +3.0 | +1.7 | + .5 | +51 | 0 | + .6 | +.1 | +7 | + .04 | +.960 | +1.007 |
| | 2 | + .1 | + 67 | +37 | + 9 | +1.7 | +1.2 | + .7 | +41 | 0 | + .3 | +.1 | +1 | + .01 | +.650 | + .707 |
| | 3 | + .1 | + 62 | +27 | + 8 | +1.5 | + .9 | + .6 | +29 | 0 | + .1 | +.1 | -1 | - .01 | +.571 | + .462 |
| White Tail 3-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | -1.0 | - 8 | - 4 | - 5 | - .6 | +4.0 | + .6 | -20 | 0 | +2.1 | 0 | +1 | + .41 | -.171 | - .218 |
| | 2 | - .8 | - 9 | - 7 | - 5 | - .3 | +4.0 | - .2 | -17 | 0 | + .8 | 0 | 0 | + .15 | -.181 | - .245 |
| | 3 | - .5 | + 2 | - 5 | - 5 | - .5 | +3.0 | + .1 | -10 | 0 | + .8 | +.1 | +1 | + .01 | -.210 | - .114 |
| White Tail 3-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .8 | + 17 | +15 | -1 | + .5 | +2.0 | +1.1 | 0 | 0 | + .9 | +.1 | +1 | +1.8 | +.090 | + .179 |
| | 2 | - .3 | + 12 | + 4 | -1 | - .1 | +1.8 | + .5 | + 1 | 0 | + .3 | +.1 | -1 | + .16 | +.009 | + .021 |
| | 3 | - .2 | + 15 | + 4 | -1 | - .1 | +1.6 | + .2 | + 1 | 0 | + .1 | +.1 | 0 | + .39 | -.009 | + .052 |
| White Tail 4-1 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | -1.0 | + 13 | +12 | -2 | +1.0 | +3.0 | +2.1 | - 1 | 0 | +1.6 | 0 | +4 | + .30 | +.150 | + .133 |
| | 2 | - .4 | + 9 | 0 | -2 | 0 | +2.0 | + .3 | - 2 | 0 | + .5 | 0 | 0 | + .01 | -.036 | - .018 |
| | 3 | - .3 | + 6 | - 1 | -1 | - .1 | +1.0 | 0 | - 2 | 0 | + .1 | 0 | 0 | - .04 | -.033 | - .033 |
| White Tail 4-2 | Applied | 7.5 | 208 | 129 | 27 | 5.9 | 8.0 | 3.3 | 90 | 0 | 2.1 | 0.1 | 30 | 0.11 | 2.181 | 2.172 |
| | 1 | - .1 | + 14 | + 4 | -1 | 0 | +1.8 | + .1 | 0 | 0 | + .3 | 0 | +2 | + .05 | -.008 | + .054 |
| | 2 | - .1 | + 8 | + 3 | 0 | - .1 | +1.5 | 0 | 0 | 0 | + .3 | +.1 | 0 | + .01 | +.030 | + .014 |
| | 3 | - .2 | + 7 | +17 | 0 | + .5 | +1.3 | + .3 | + 4 | 0 | +1.1 | +.1 | +3 | +1.4 | +.087 | + .271 |
| | 4 | - .1 | + 8 | + 6 | 0 | + .4 | +1.4 | + .3 | + 2 | 0 | + .3 | +.1 | -2 | + .25 | +.081 | + .023 |

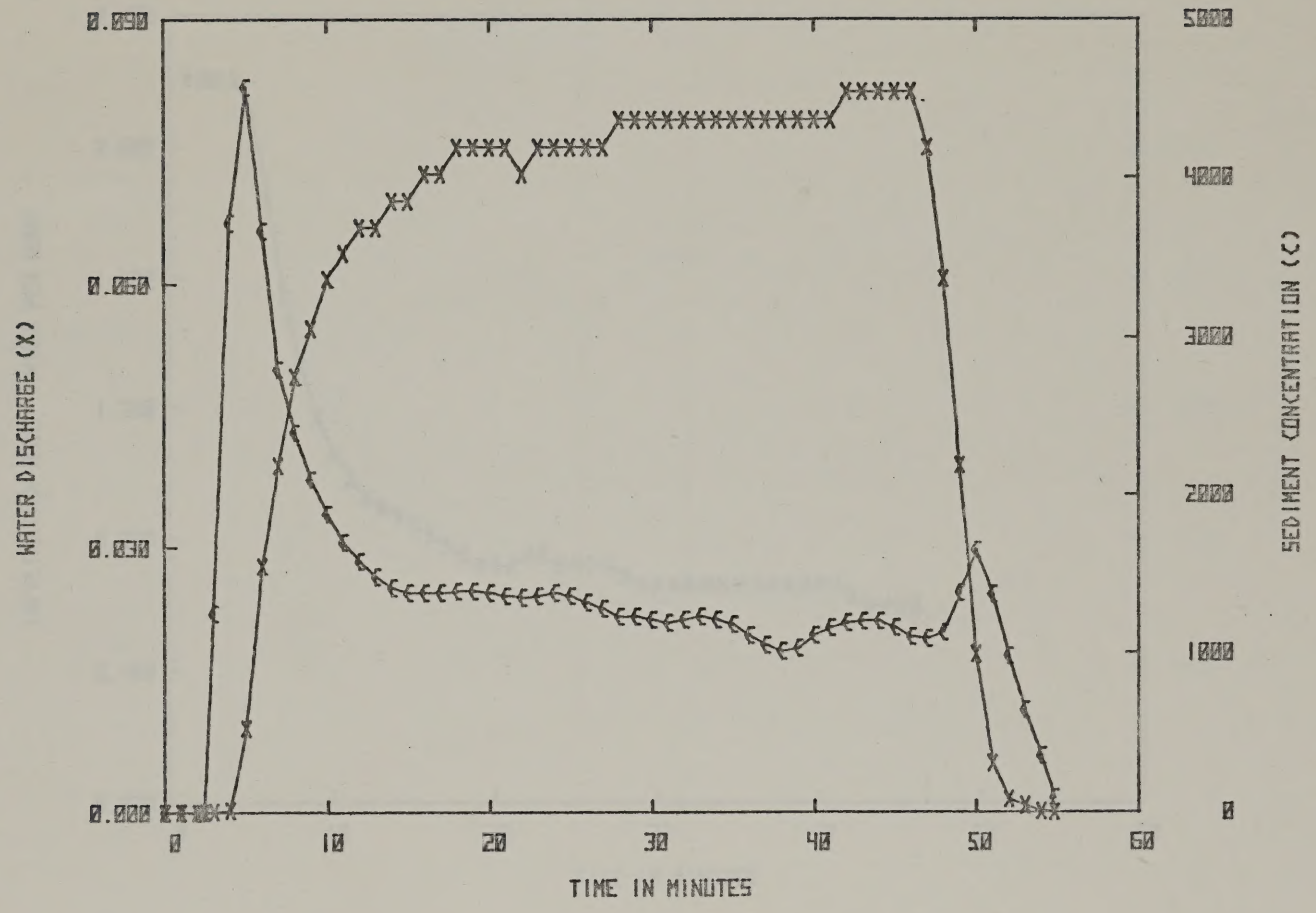



WHITE TAIL BUTTE 1-1 DRY 8-19-76

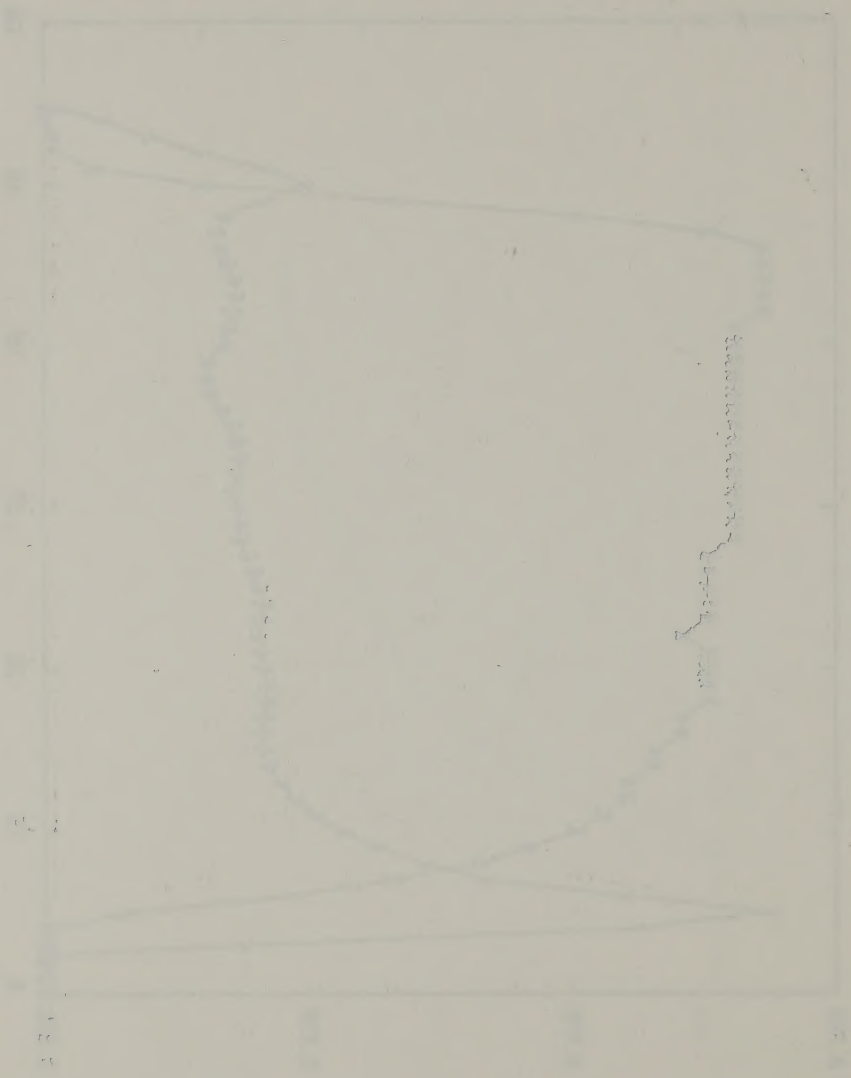


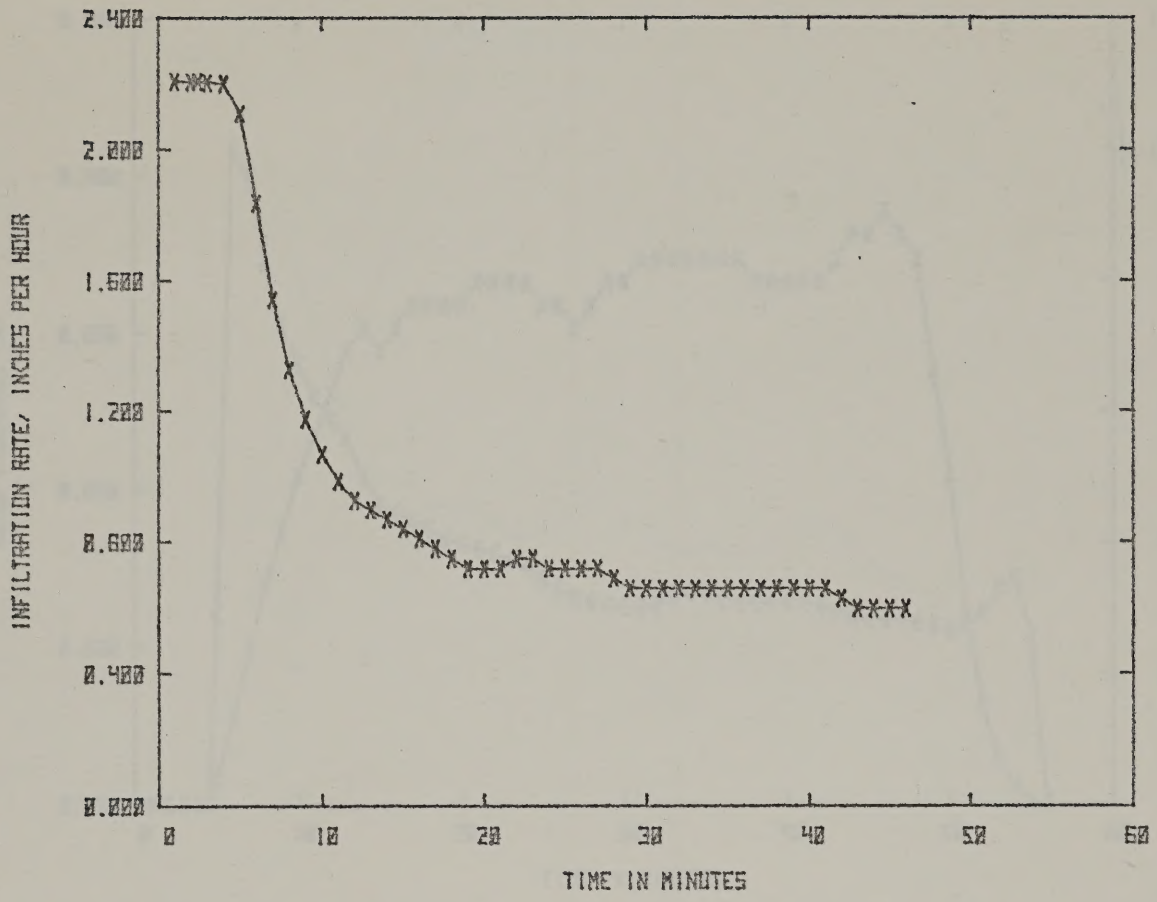



WHITE TAIL BUTTE 1-1 DRY

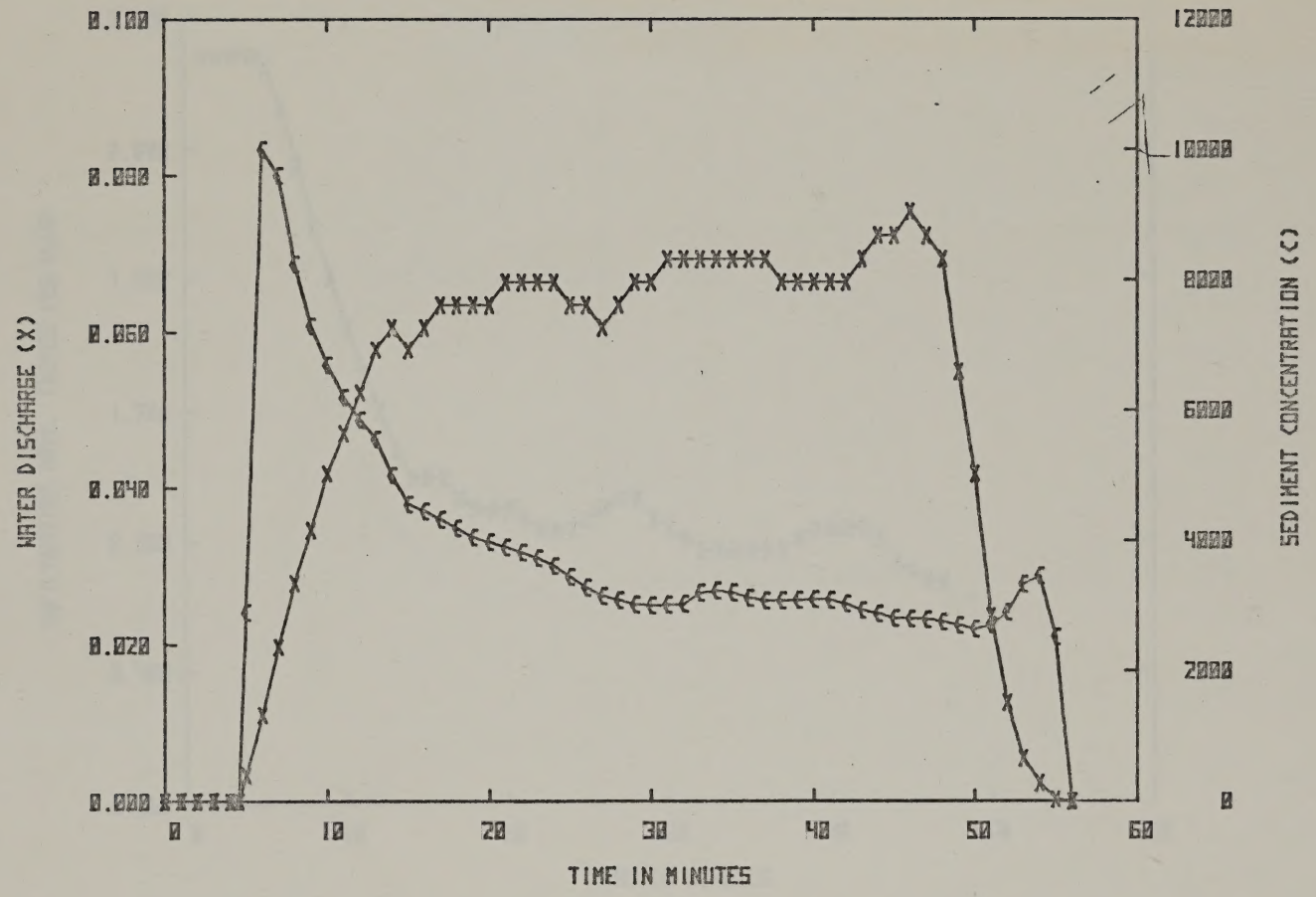



WHITE TAIL BUTTE 1-2/WET 8-20-76





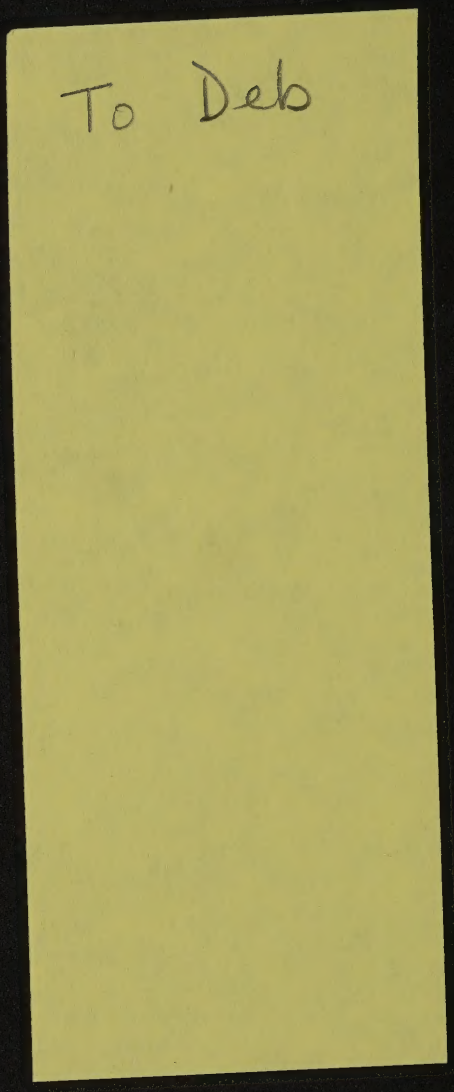

WHITE TAIL BUTTE 1-2/WET 8-28-76

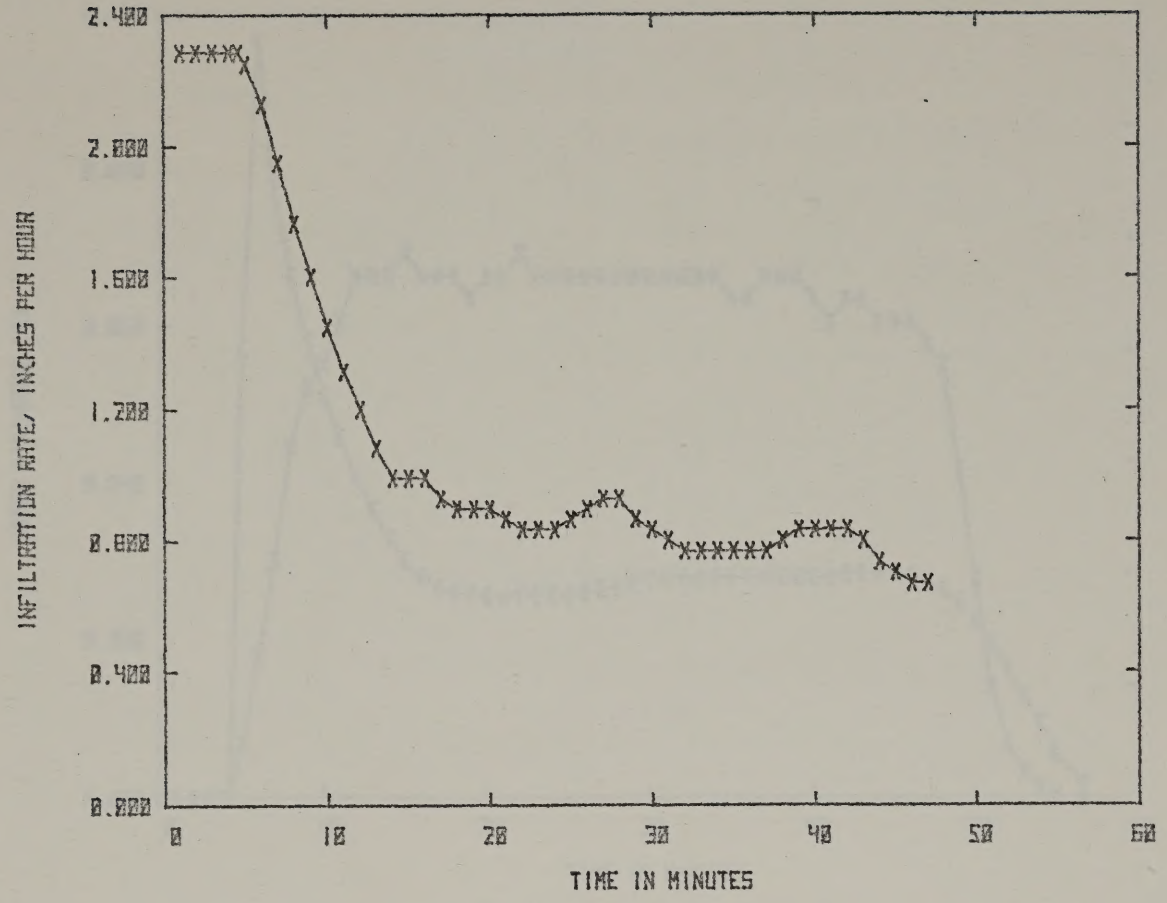



WHITE TAIL BUTTE 2-1 DRY 8-22-76

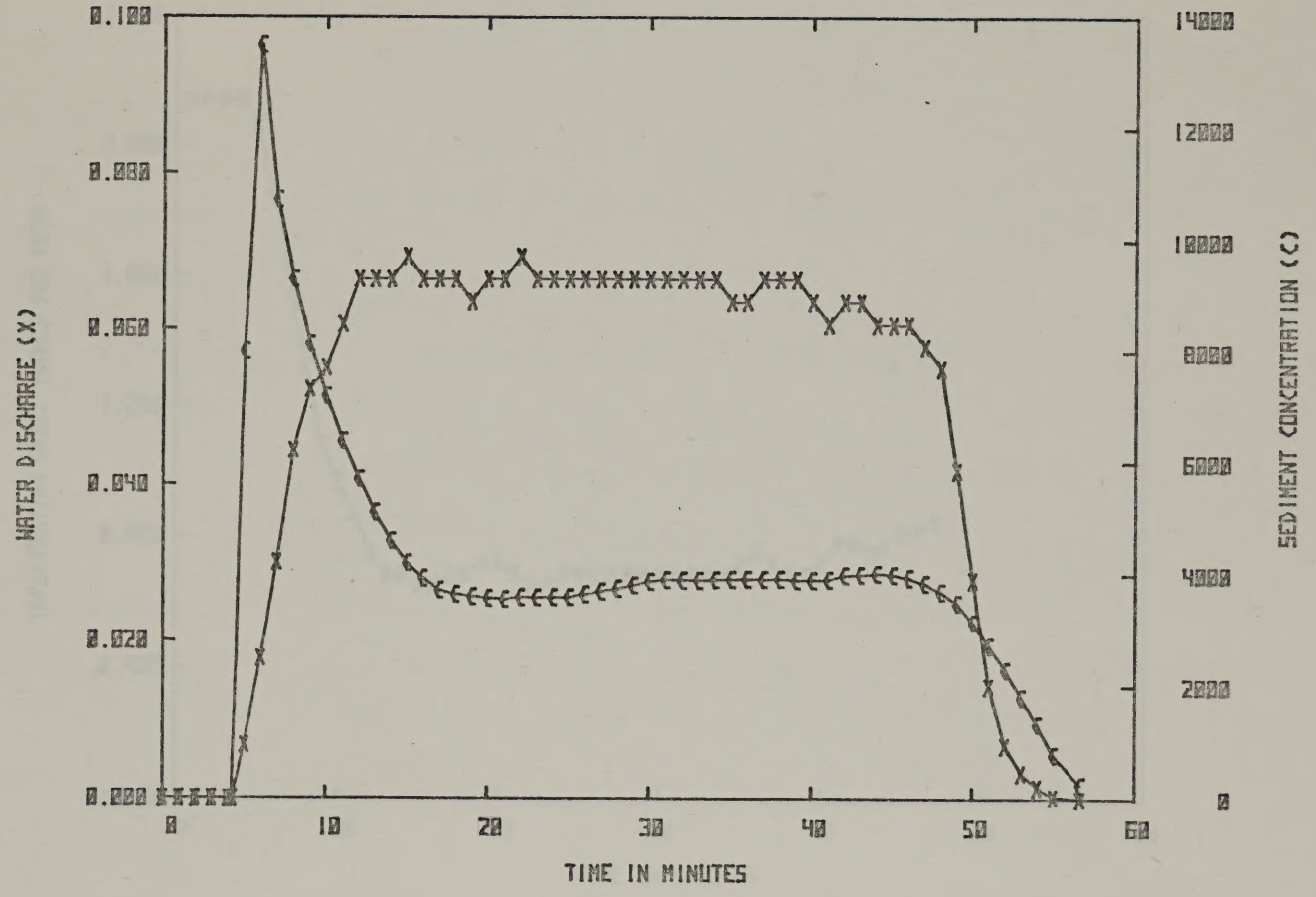
007

electronic resource

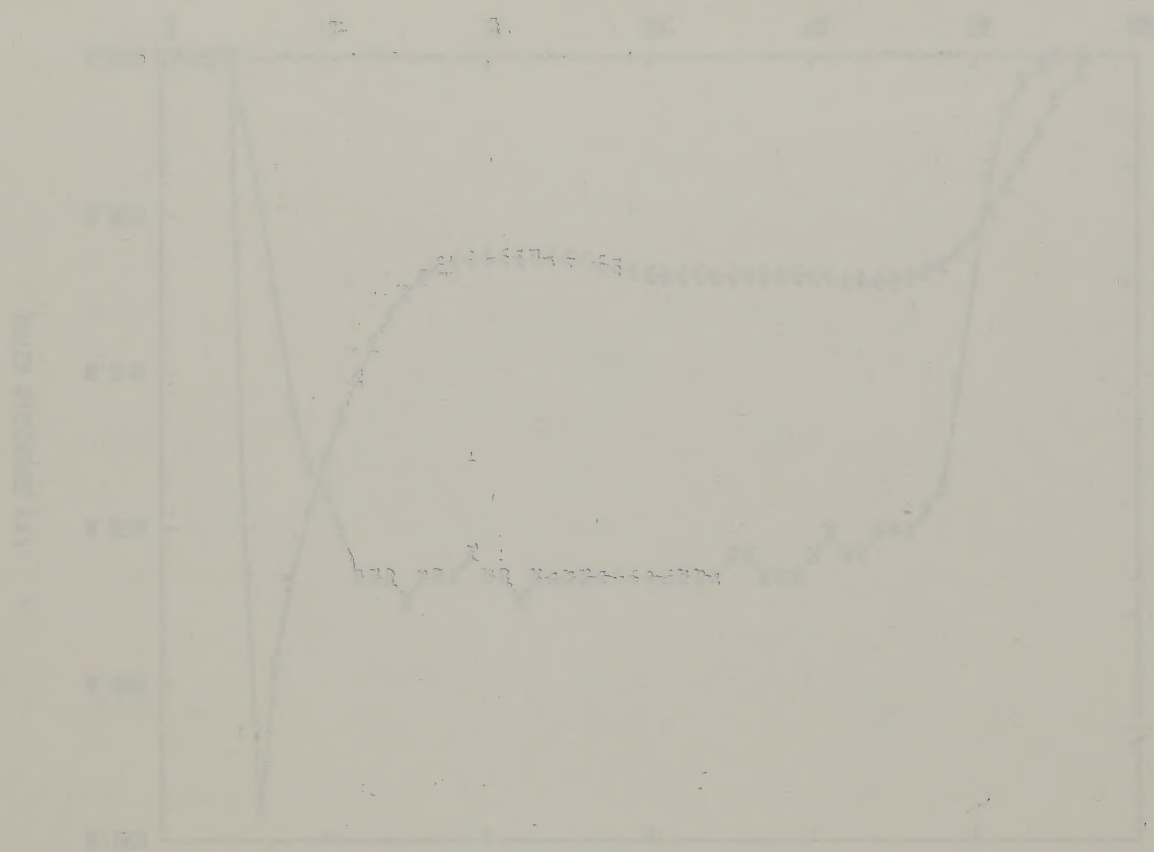

To Deb

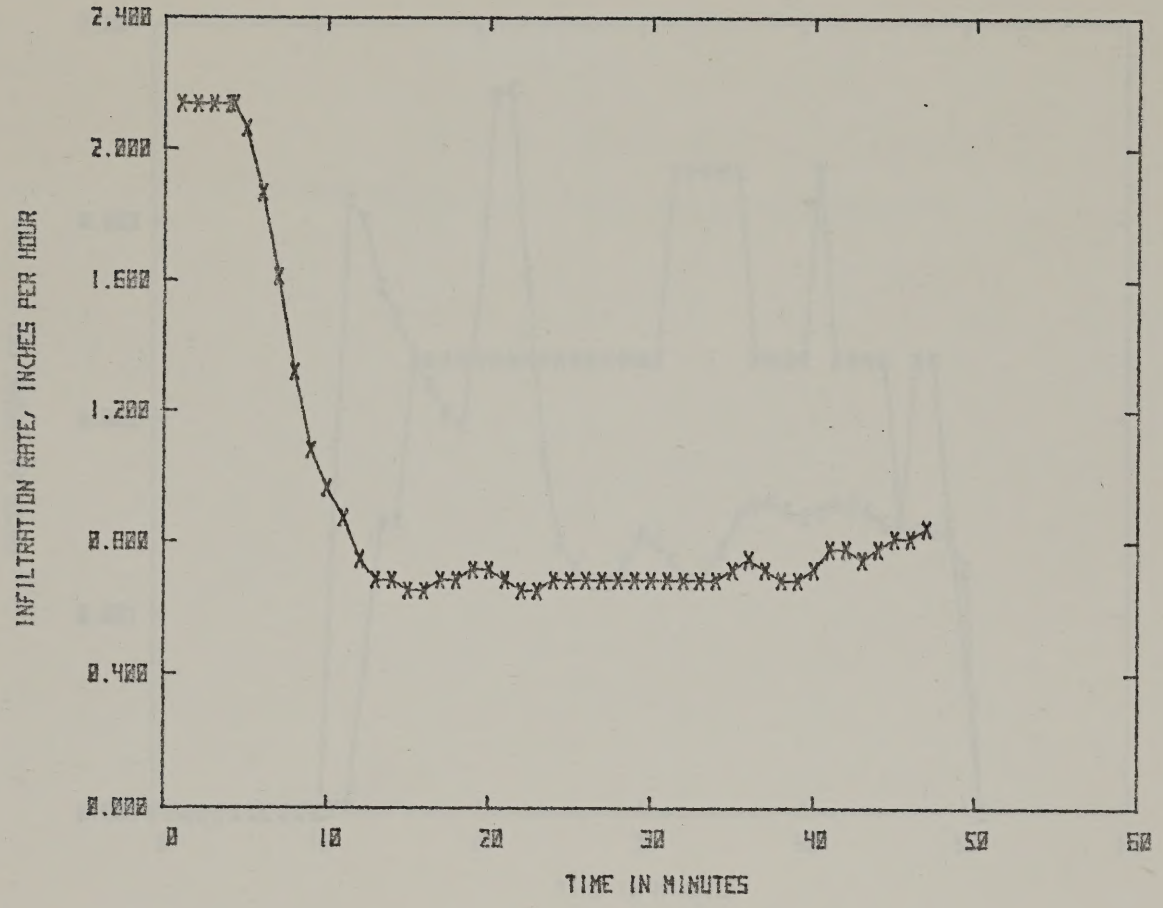



WHITE TAIL BUTTE 2-1 DRY 8-22-76

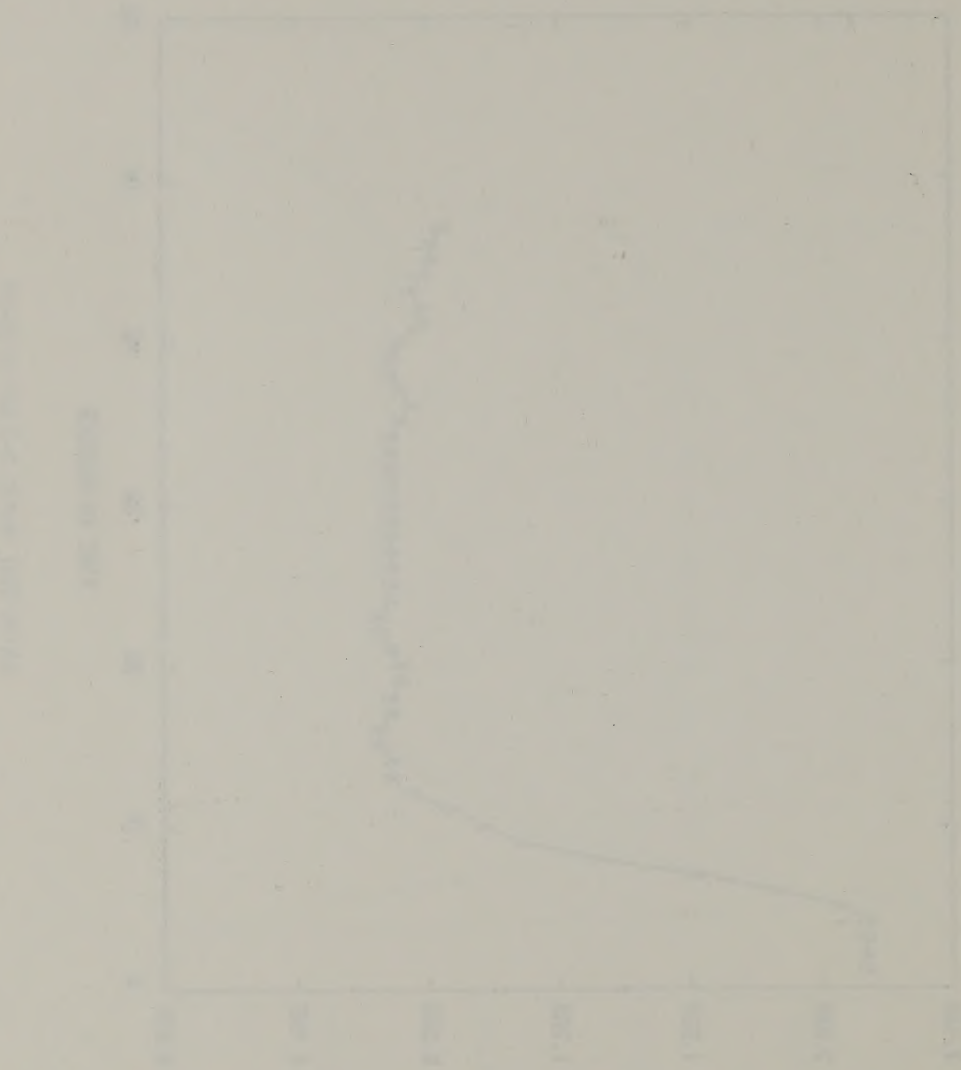


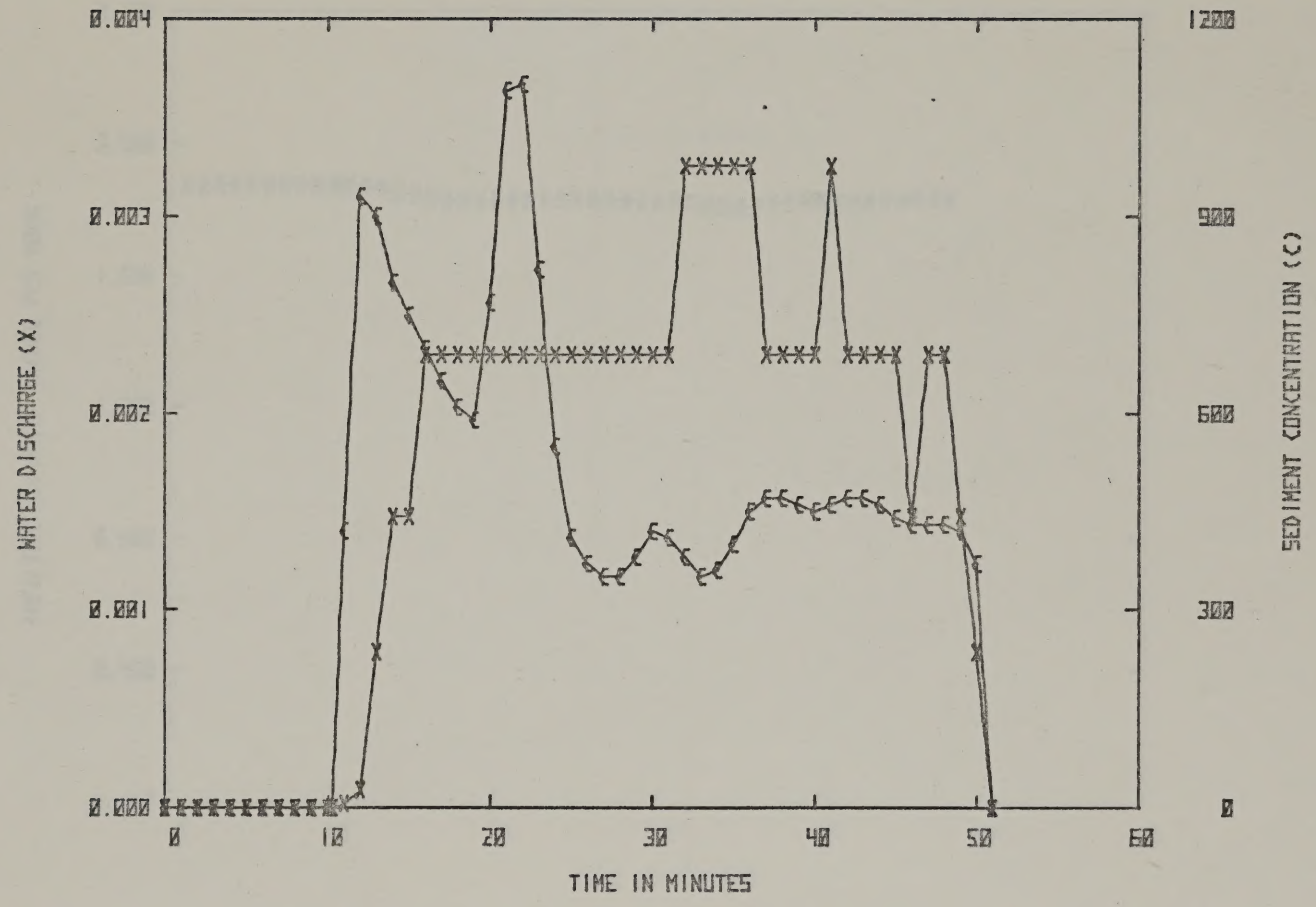

WHITE TAIL BUTTE 2-2 WET 8-23-76



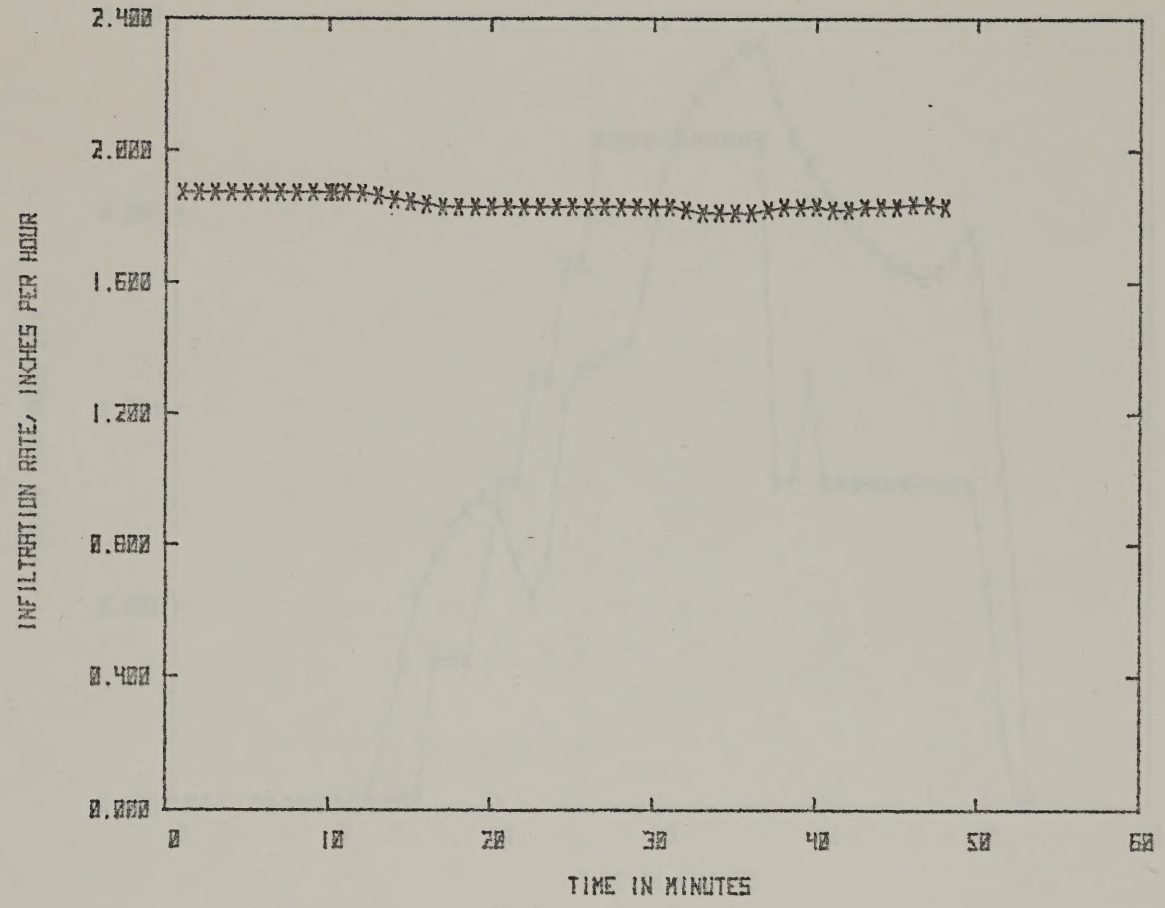



WHITE TAIL BUTTE 2-2 WET 8-23-76

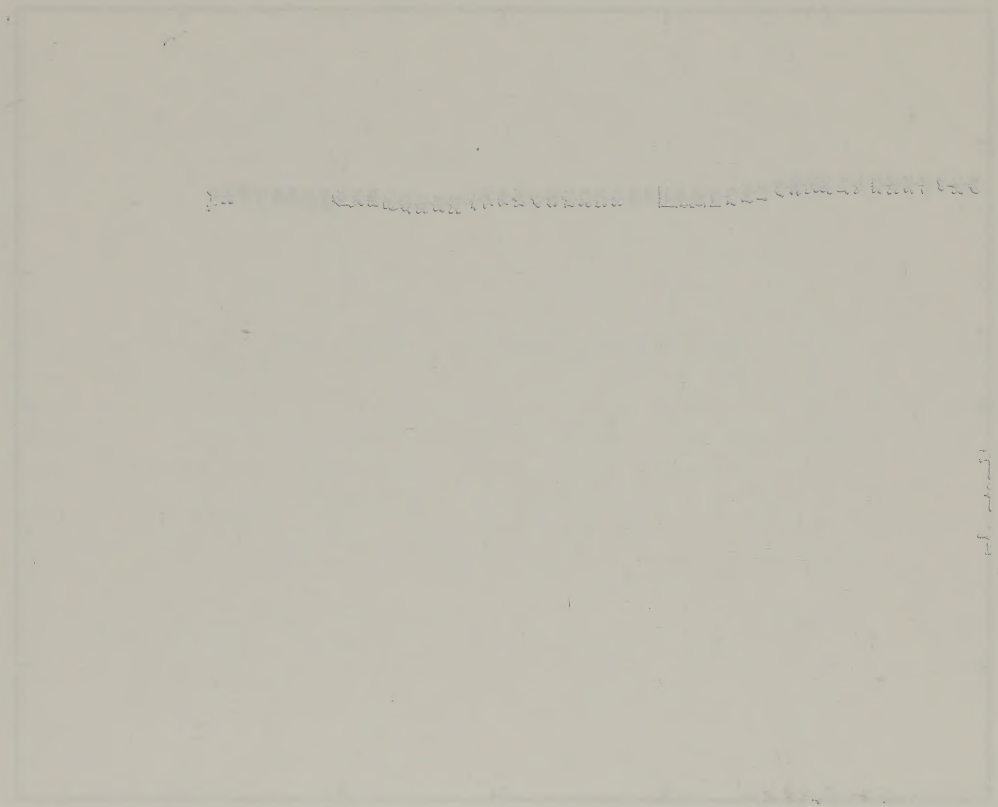


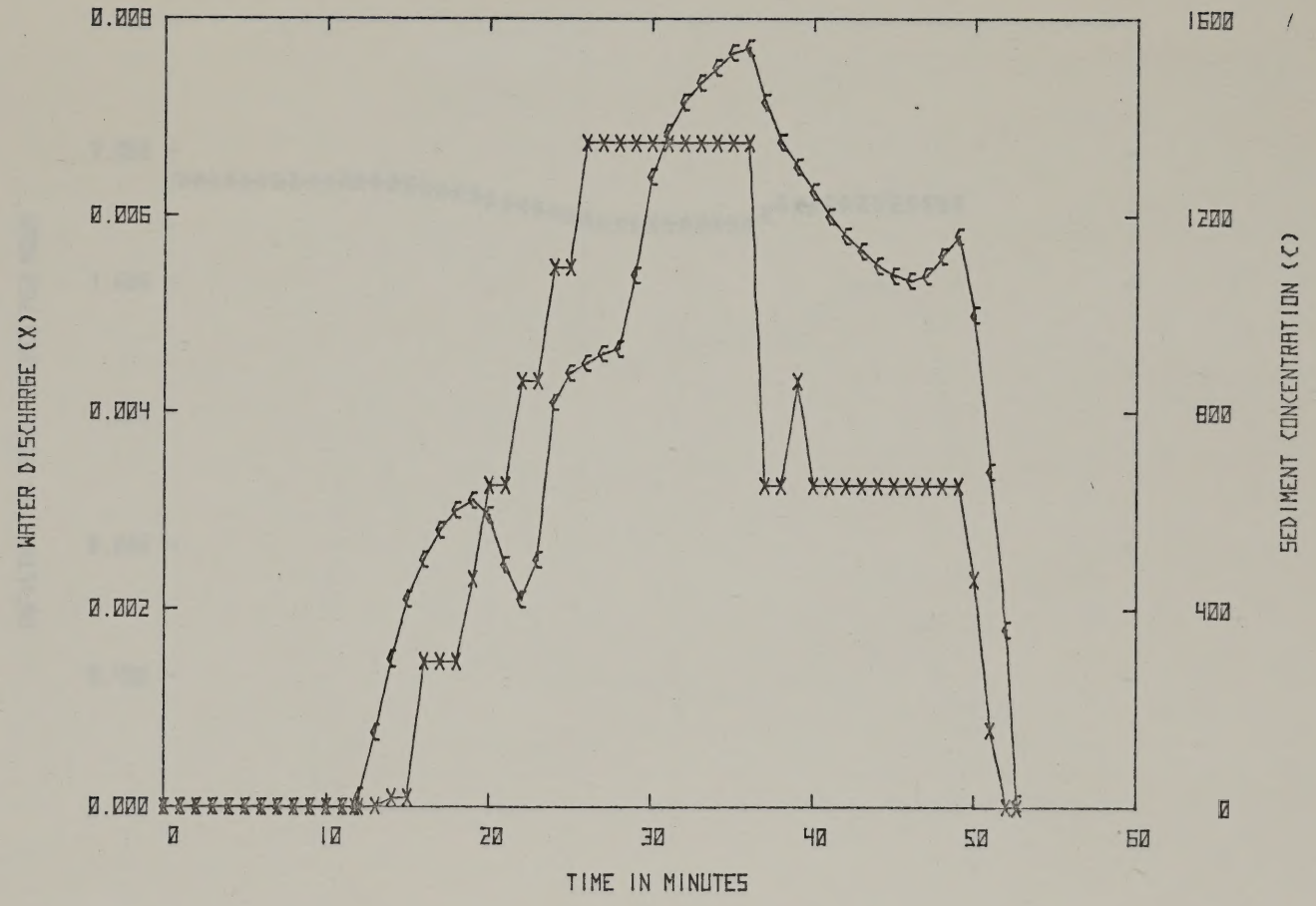



WHITE TAIL BUTTE 3-1 DRY 8-17-76

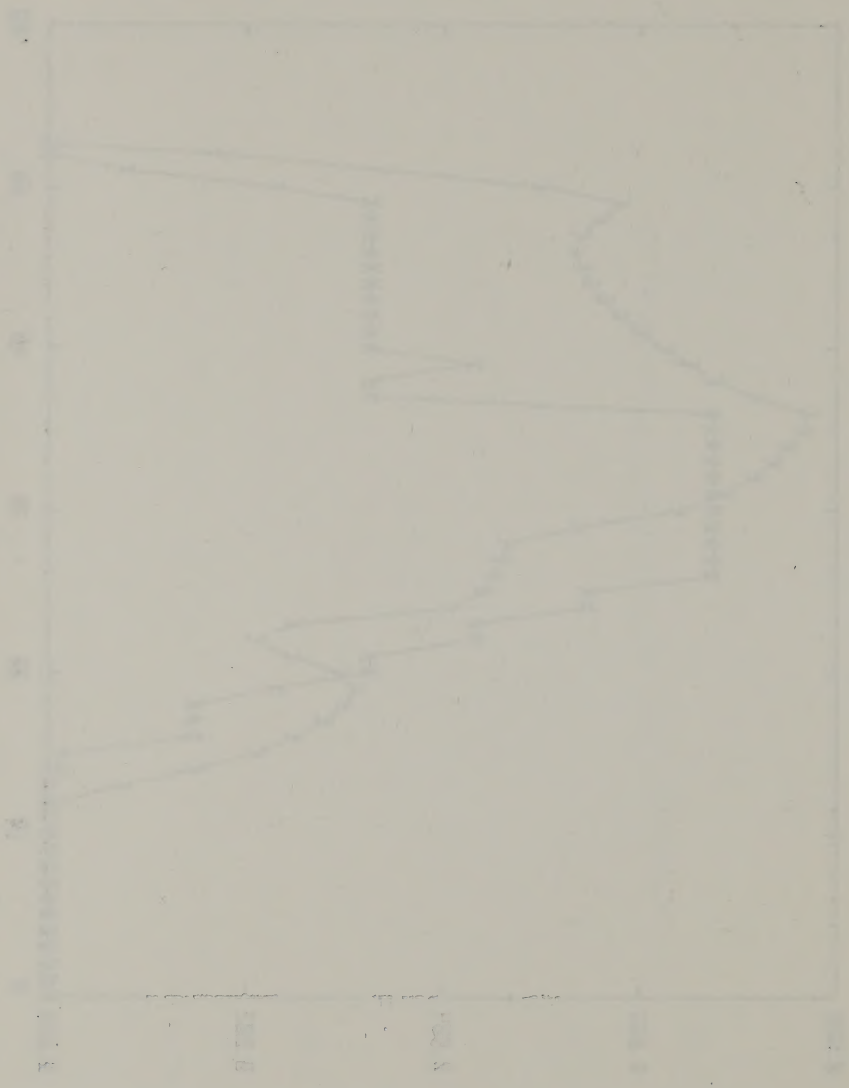


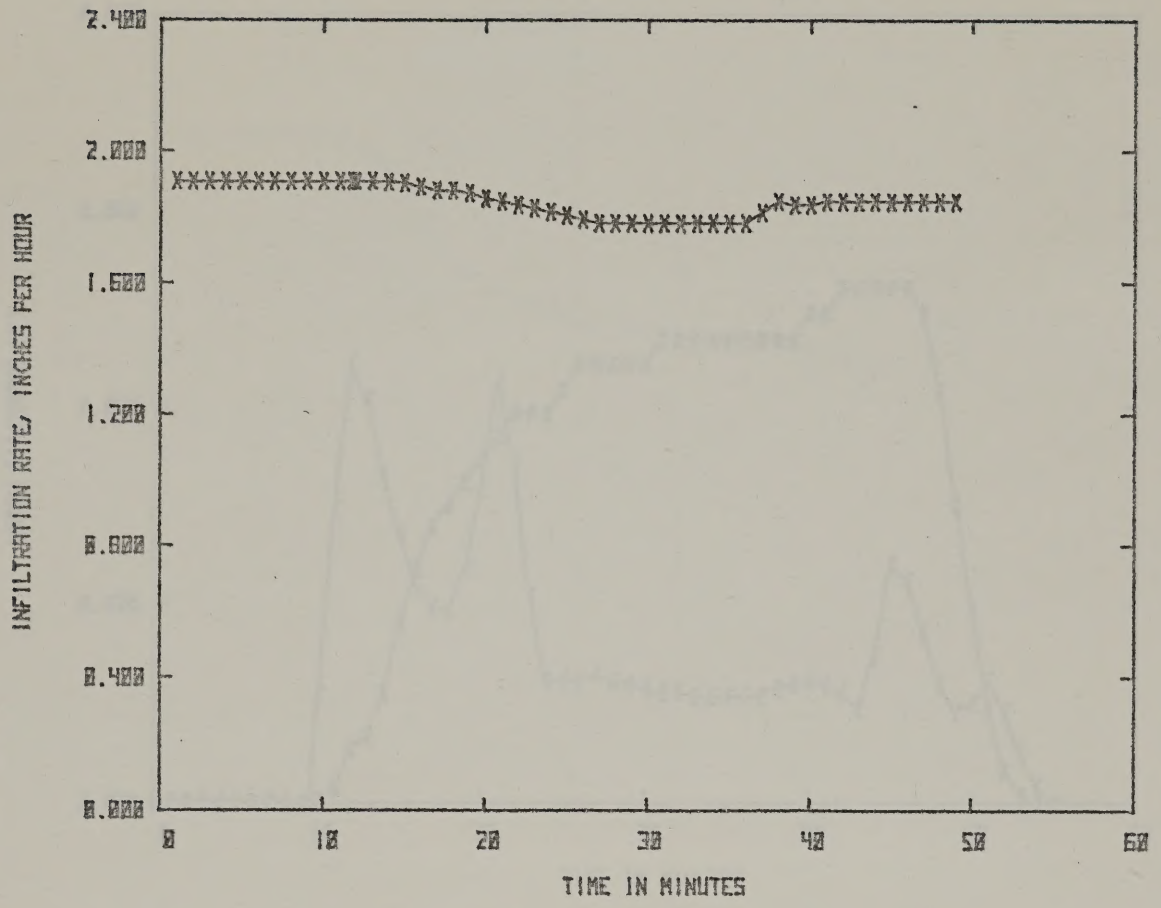

WHITE TAIL BUTTE 3-1 DRY 8-17-76



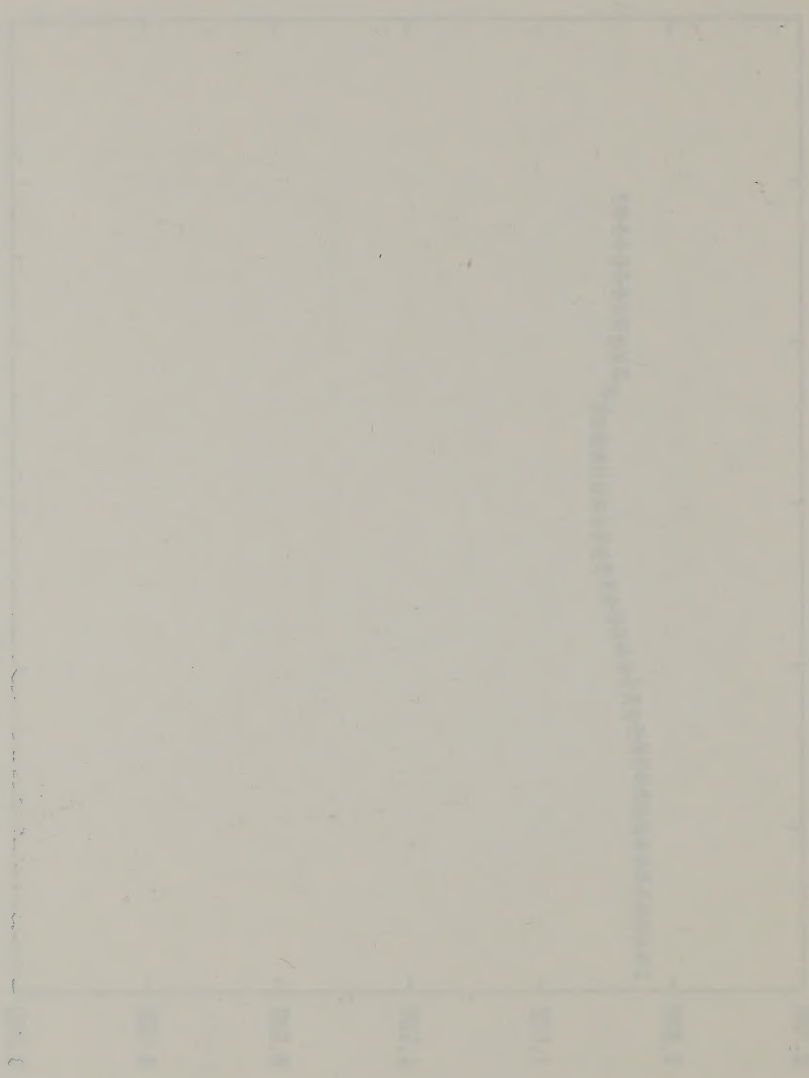


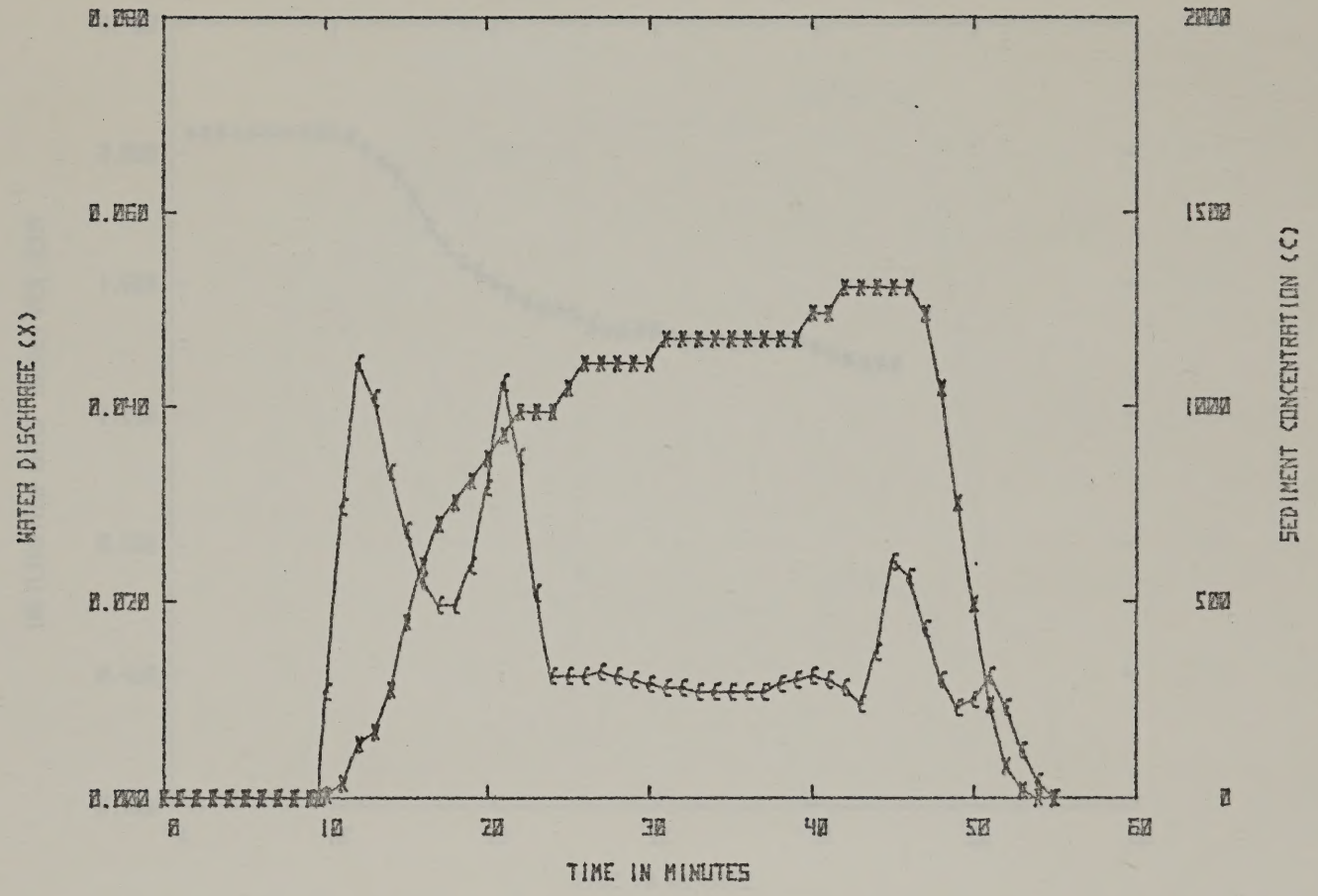

WHITE TAIL BUTTE 3-2 WET 8-18-76



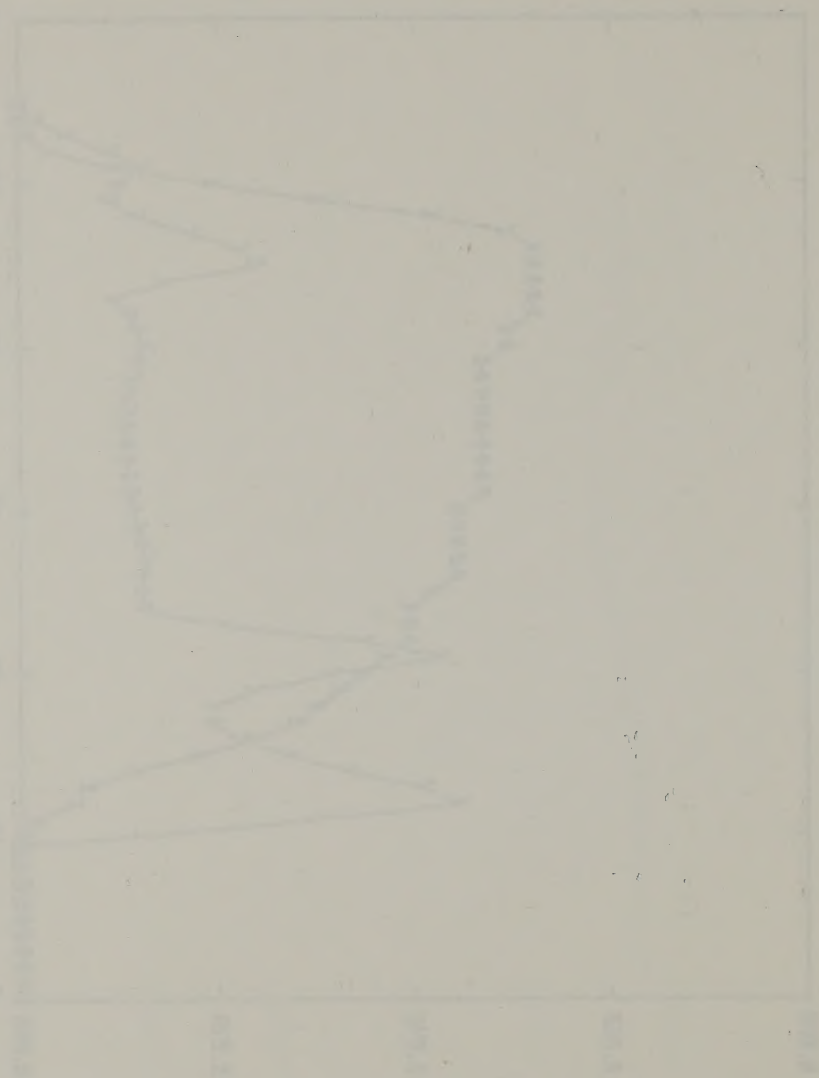


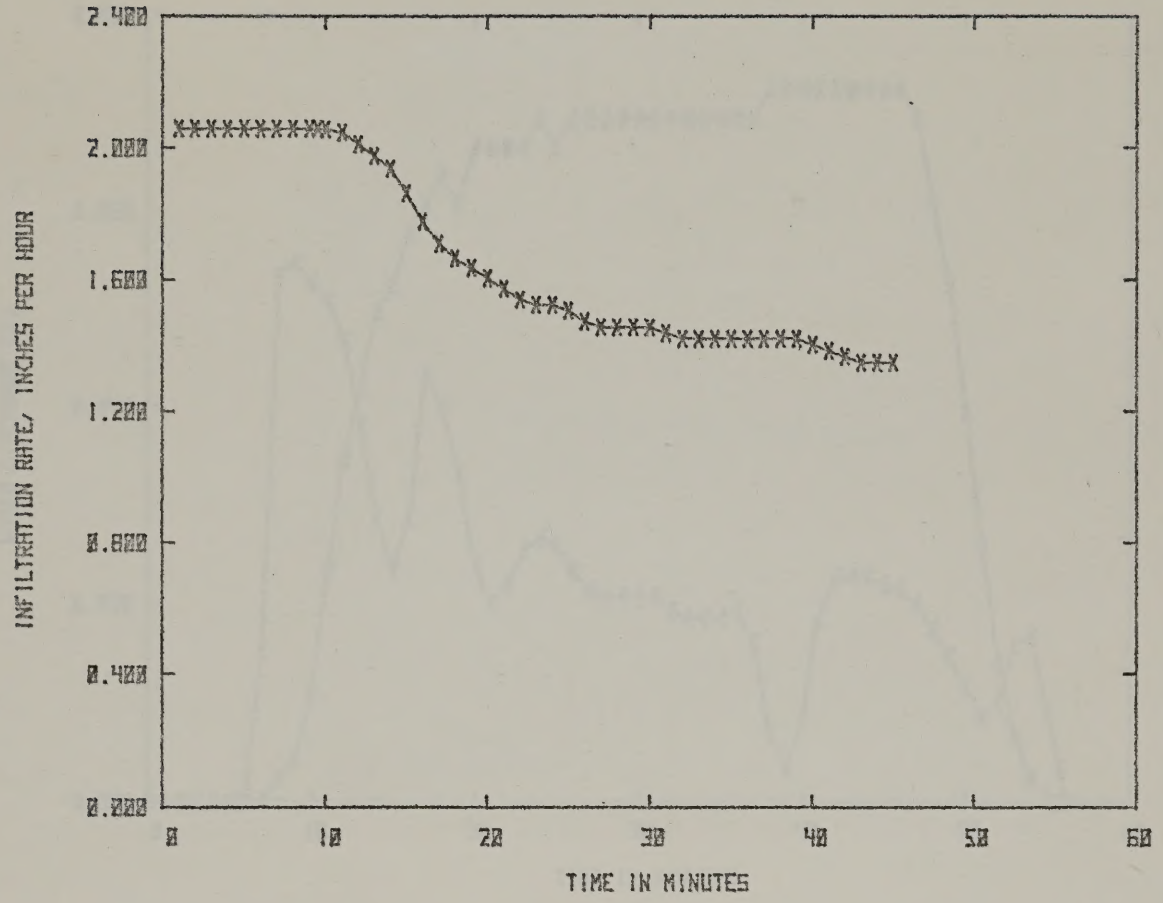

WHITE TAIL BUTTE 3-2 WET 8-18-76



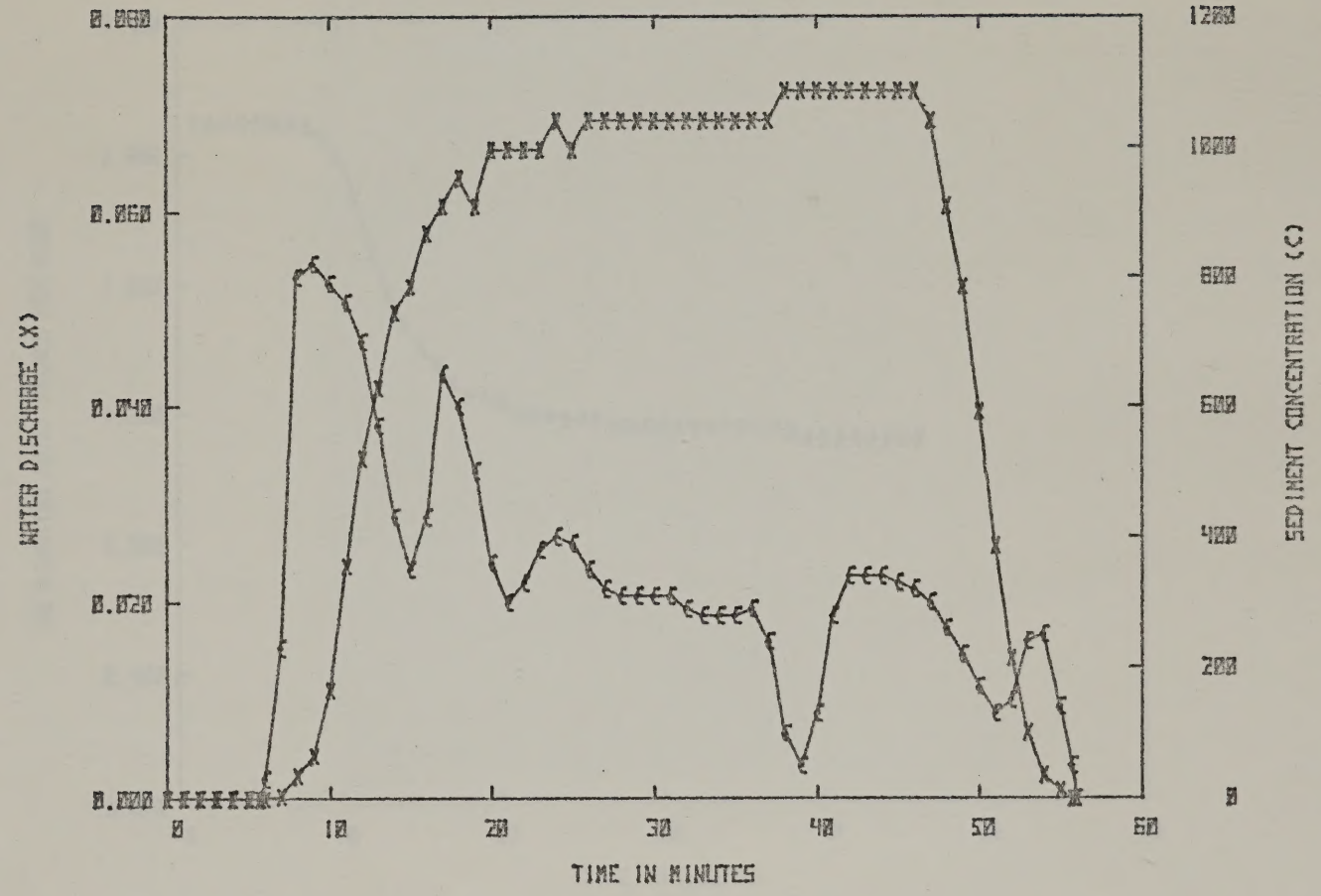



WHITE TAIL BUTTE 4-1 DRY 8-12-76

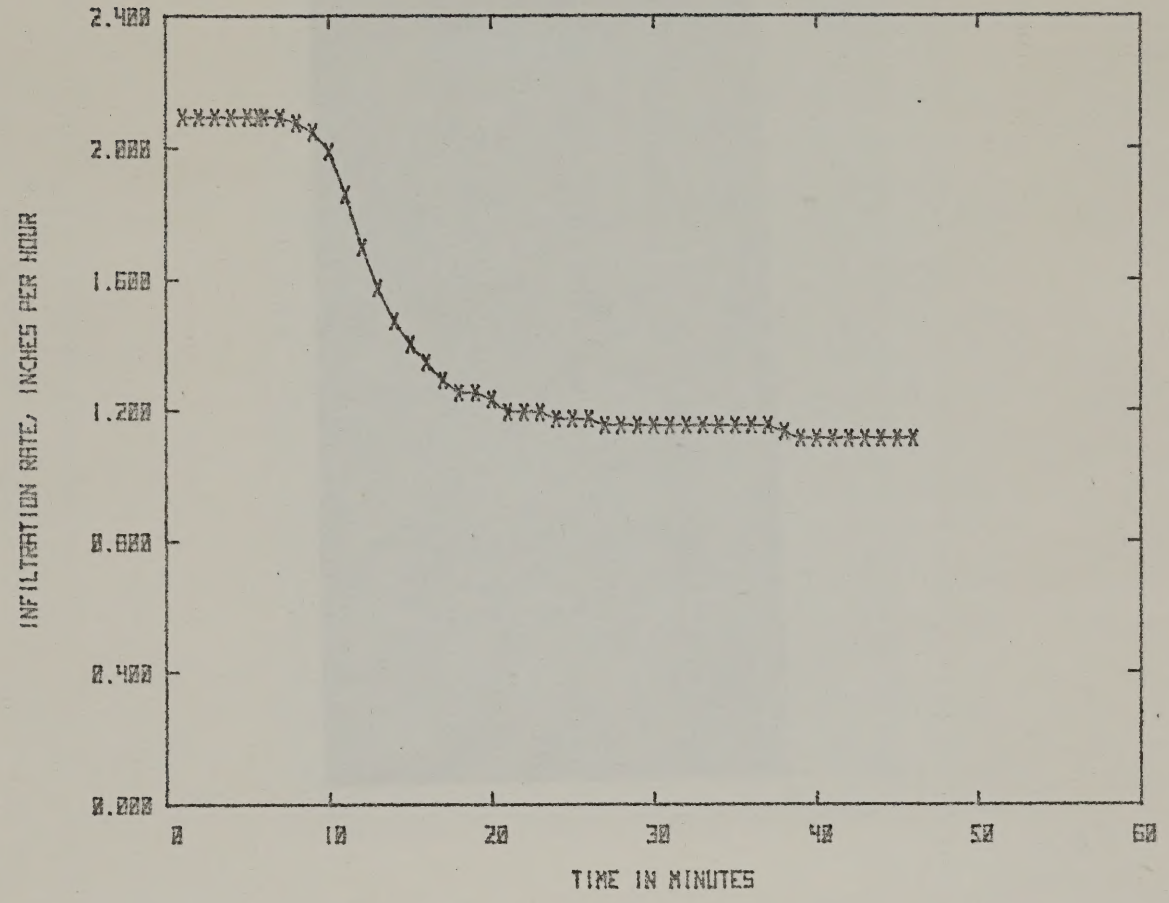




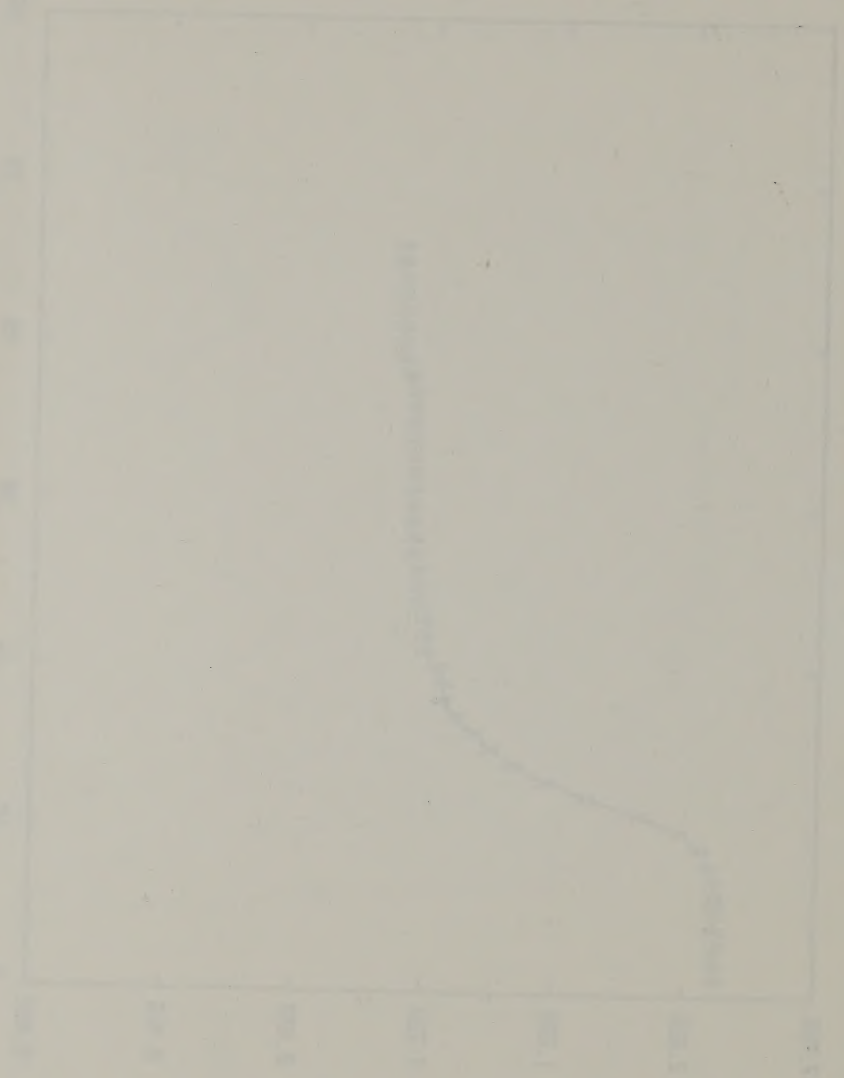

WHITE TAIL BUTTE 4-1 DRY 8-12-76




WHITE TAIL BUTTE 4-2 NET 6-13-76



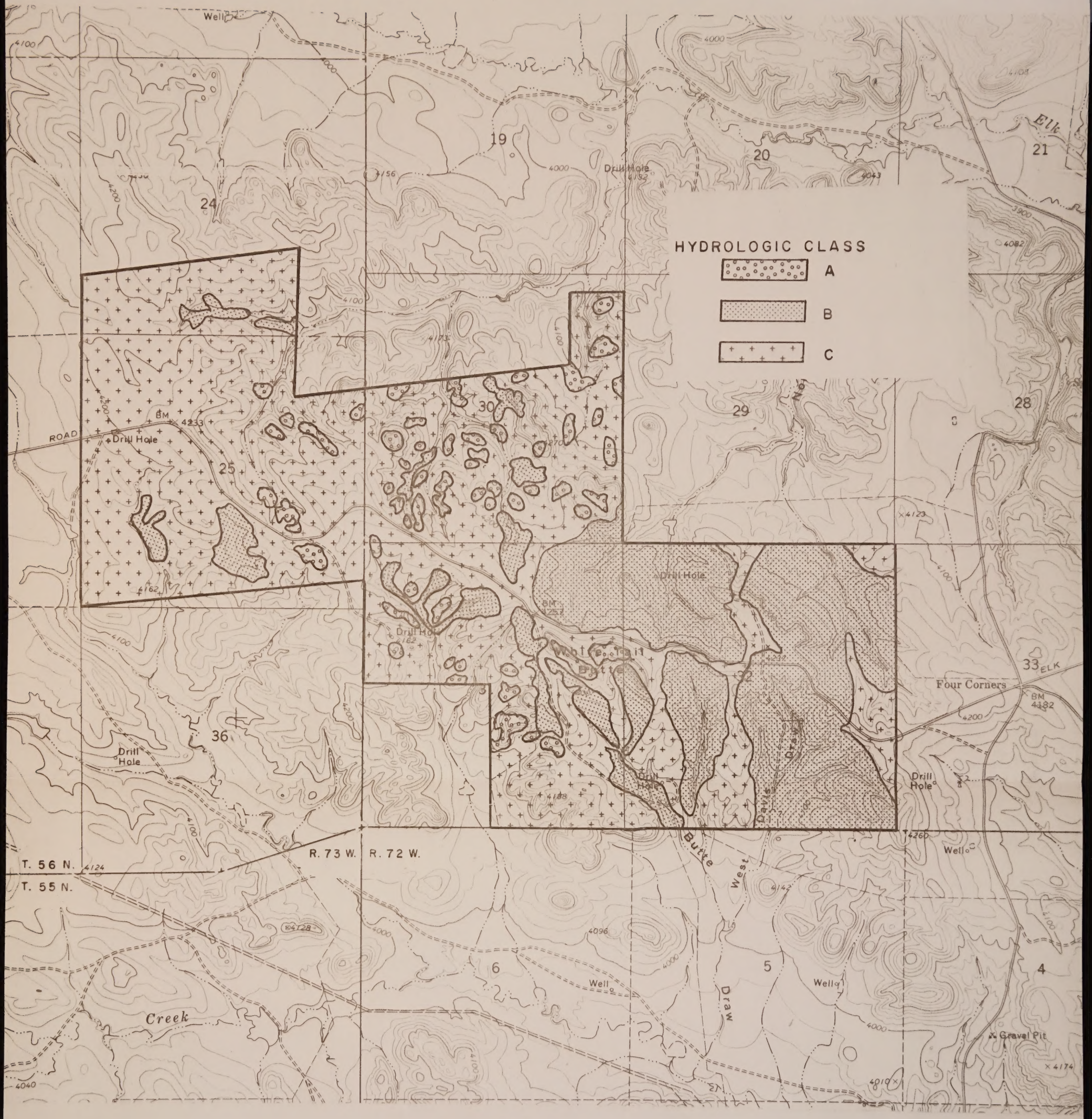

WHITE TAIL BUTTE 4-2 WET 8-13-76



White Tail Butte simulation site 1

White Tail Butte simulation site 2

White Tail Butte simulation site 4




1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

EMRIA site White Tail Butte Wyoming showing hydrologic classes